BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 02039

SUBJECT: Alternative Designs for the Television Transmission System of the Lunar Communications Relay Unit (LCRU) and their Communication Link Performance - Case 320

DATE: February 4, 1970

FROM: R. L. Selden

ABSTRACT

Two design alternatives are proposed which allow the television transmitter power of the LCRU to be reduced from ten watts to five watts. These are 1) reducing the transmitter power to five watts while maintaining the antenna size equivalent to that of a 30 inch parabolic reflector and 2) reducing the television transmitter power to five watts and increasing the antenna size to the equivalent of a 42 inch parabolic reflector. These changes would reduce the heat dissipation problem and depending on the usage duty cycle of television could possibly reduce battery weight.

The first alternative should have little effect on the performance of color television (2MHz video bandwidth) when the signal is received by a station of the MSFN equipped with a 210 foot diameter antenna. To obtain good quality slow scan black and white television (video bandwidth of 500KHz) at an MSFN station equipped with an 85 foot diameter antenna will require a bandpass filter of approximately 2.5MHz be installed in front of the wideband FM demodulator. If system elements are specified as maximum loss or minimum gain, sufficient margin should exist in the system to insure adequate television performance for this alternative design.

The second alternative provides the same margin as the system being proposed with the cost being a larger antenna. Reevaluation of the use of a larger antenna seems to be in order, particularly if the LCRU will always be transported by a Lunar Roving Vehicle.

(NASA-CR-112560) ALTERNATIVE DESIGNS FOR THE TELEVISION TRANSMISSION SYSTEM OF THE LUNAR COMMUNICATIONS RELAY UNIT /LCRU/ AND THEIR COMMUNICATION LINK PERFORMANCE (Bellcomm, Inc.) 6 p

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MEMORANDUM FOR FILE

The LCRU is intended to provide astronaut to earth and earth to astronaut communications from the lunar surface when the astronauts are out of line-of-sight of the Lunar Module. The proposed design for this unit, I believe, could be modified with the goal of reducing its physical size as well as weight while maintaining sufficient communications performance. Two alternatives are proposed, both aimed at reducing the amount of heat that would have to be dissipated and possibly the prime power required and hence the weight of the batteries. These two alternatives are 1) reduce the power of the television transmitter from ten watts to five watts while maintaining the antenna size at that equivalent to a 30 inch parabolic reflector, and 2) reduce the power of the television transmitter from ten watts to five and increase the equivalent antenna size to that of a 42 inch parabolic reflector.

The first alternative reduces the received signal level at the MSFN ground station by 3dB while the second alternative provides the same signal level as the proposed system but at a cost of increased antenna size. The rationale behind these two alternatives and their communications performance is discussed in the subsequent paragraphs.

The first alternative reduces television transmitter power while maintaining all other system parameters. The natural question is, "So we buy a lower thermal load and less battery drain, what happens to television performance when we lower the received signal power by a factor of 2 (3dB)?". As a starting point, I want to present the current (2-3-70) LCRU design and compare its performance with that of the LM and CSM television links. This comparison is presented in Table I. The data in Table I indicates that the currently proposed LCRU design for television transmission provides signals at the MSFN that are comparable to that of either the CSM or the LM using their steerable antennas. The data in Table I also indicates an important difference in the color television channel as compared to the slow scan black and white channel. Comparable signal designs for color and black and white slow scan television would yield the same signal-to-noise ratio at a given receive station. Comparison of line items 10 and 11 on Table I shows that this is not the case. The wideband color system is more like an AM system while the narrow band slow scan black and white system does derive the advantage of FM. This is a significant point when considering a reduction of LCRU transmitter power of 3dB. For color television to a station equipped with a 210 foot diameter antenna, reducing the LCRU transmitter power from ten watts to five results in a 3dB reduction in video SNR (peak-to-peak signal to rms noise). This would probably not be a significant change to most viewers and indeed would still provide a better color television picture than a CSM transmitting to an MSFN station equipped with an 85 foot antenna (which experience has shown to be a picture of usable quality).* This same thing is not true when considering the transmission of the slow scan black and white television signal to an MSFN station equipped with an 85 foot diameter antenna; Table I shows that a 3dB reduction in LCRU transmitter power reduces the received SNR to 5.6dB (in a 5.3MHz bandwidth) which is below the ground stations demodulator threshold. Television picture SNR is difficult to calculate below threshold and is unreliable. There is a solution to this problem, however; the most easily accomplished solution is to reduce the MSFN receiver input bandwidth to some value less than 5.3MHz and thereby raise the input SNR to a value above threshold. Classic FM theory and empirical data provide two tools to allow halving the LCRU television transmitter power. These are 1) as the ratio of the input bandwidth to output bandwidth is reduced, the threshold is also reduced** and 2) the energy of the rf spectrum of the slow scan television signal when deviating an rf carrier ±1.0MHz or more is almost entirely contained within an rf bandwidth

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*In fact, from Table I, the received signal power at a station equipped with a 210 foot diameter antenna when you reduce the LCRU transmitter power 3dB is -124.5dBW. This is within a half dB of the specified performance for this channel during the Apollo 12 mission. (REF: "Communications Systems Performance and Coverage Analysis for Apollo 12 (H-1 Mission) Mission Summary", MSC Internal Note #MSC-00-173, October 31, 1969) It also represents a signal level that is 2.5dB higher than that implied as the minimum required by the LCRU Request for Proposal.

**Downing, J. J., Modulation Systems and Noise, Prentice Hall, 1964.

equal to twice the deviation. Thus, if a 2.5MHz* bandpass filter were added in front of the ground station demodulator, item 9 of Table I would become 11.9dB and with a 3dB reduction of LCRU transmitter power, the received signal power would become 8.9dB. This should be 1-2dB above threshold and should provide an output video peak-to-peak to rms noise ratio of 32.8dB.**

The second alternative of reducing the LCRU television transmitter power to five watts while increasing the equivalent antenna diameter to 42 inches will provide the same performance as that shown in Table I. The penalty associated with this option is the larger antenna aperture required and the somewhat more difficult antenna pointing problem. If it is assumed that the LCRU, when used for television, will always be carried on the Lunar Roving Vehicle (LRV), the original desire of eliminating a bulky antenna that has to be transported manually tends to go away. It is recognized that the location of a 30 or 42 inch antenna on the LRV may also be a problem; it seems to me, through, that this problem deserves some reevaluation. If the astronaut is to get off the LRV to aim the antenna toward earth, regardless of size, a 42 inch antenna (3dB beamwidth of 8°) may not be much more difficult to point than a 30 inch antenna (3dB beamwidth of 12°).

In summary, it would seem that the price of a bandpass filter at a few stations of the MSFN would be a relatively low price to pay to lower the thermal radiation requirements of the LCRU, as well as possibly reducing the battery requirement (the battery requirement will be a function of the television usage duty cycle). The first alternative I have proposed here actually provides television performance which exceeds Apollo specified requirements. This assumes the LCRU parameters are

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*A 2.5MHz bandwidth could be too narrow for the spectrum of the slow scan black and white television signal (i.e. 0.625 frames/second) if the LCRU FM transmitter is not provided with dc response. DC response is required or the apparent peak-to-peak deviation will be greater than that specified because of the addition of the residual input voltage level at the modulator to the normal voltage change when a scene change from black to white (or vice versa) occurs. (See: MSC Report EB2004(U), "A Communications Performance Evaluation for the Reference Lunar Landing Mission", January, 1969)

**32.8dB SNR (P-P/rms) is 4.8dB above the SNR required by the Apollo Performance and Interface Specification.

maximum-loss or minimum-gain type parameters. The second alternative* would provide the current (2-3-70) desired performance with the same potential benefits as alternative one if a slightly larger dish can be accommodated on the LRV.

R. L. Selden

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Attachment
Table I

*A third alternative might be to rely entirely on 210 foot antennas on earth. This would probably require a great deal of coordination to obviate conflicts, but would probably allow the TV transmitter power to be reduced to something less than five watts. I would not recommend this as a design approach.

TABLE I

PERFORMANCE OF THE CSM, LM AND LCRU TELEVISION LINKS

		CSM	LM		LCRU
			Nominal	Worst Case	
1.	Transmitter Power	10.5dBW	12.7dBW	11.7dBW	10.0dBW
2.	Transmit Circuit Losses	-6.6dB	-3.8dB	-4.7dB	-1.5dB
3.	Transmit Antenna Gain	25.7dB	20.5dB	20.3dB	22.0dB
4.	Antenna Pointing Loss	-0.2dB	-0.5dB	-0.5dB	-1.0dB
5.	Effective Isotropic Radiated Power	29.4dBW	28.9dBW	26.8dBW	29.5dBW
6.	Free Space Loss (215,000 N.M.)	-211.6dB	-211.6dB	-211.6dB	-211.5dB
7.	Receive Antenna Gain (85')	52.5dB	52.5dB	52.5dB	52.5dB
8.	Received Signal Power	-129.7dBW	-130.2dBW	-132.3dBW	-129.5dBW
9.	Received Signal-to-noise Ratio (SNR) (B=5.3MHz; T=210°K; KTB=-138.2dBW)	8.5dB	8.0dB	5.9dB	8.6dB
10.	Color TV - SNR P-P/rms (2MHz) Δf=2.0MHz, Fv=2.0MHz	23.5dB	23.0dB	20.9dB	23.6dB
11.	Black & White TV SNR P-P/rms Δf=1.0MHz, Fv=0.5MHz	35.5dB	35.0dB	Below Threshold	35.6dB

NOTE: For Operation With a Ground Station Equipped With a 210 Foot Diameter Antenna - Add 8dB to Items 7, 8, 9, 10 and 11.

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